Subsonic and Transonic Testing of Two Inflatable Aerodynamic Decelerators

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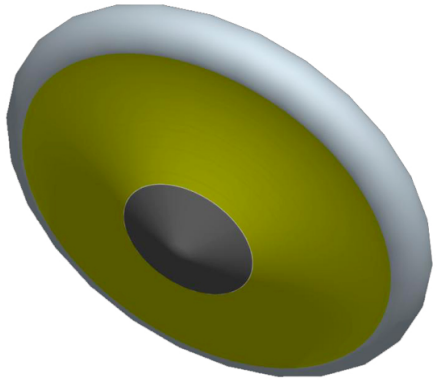
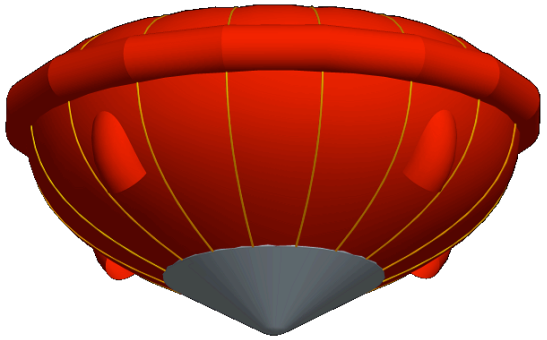




Inflatable Aerodynamic Decelerators (IADs)

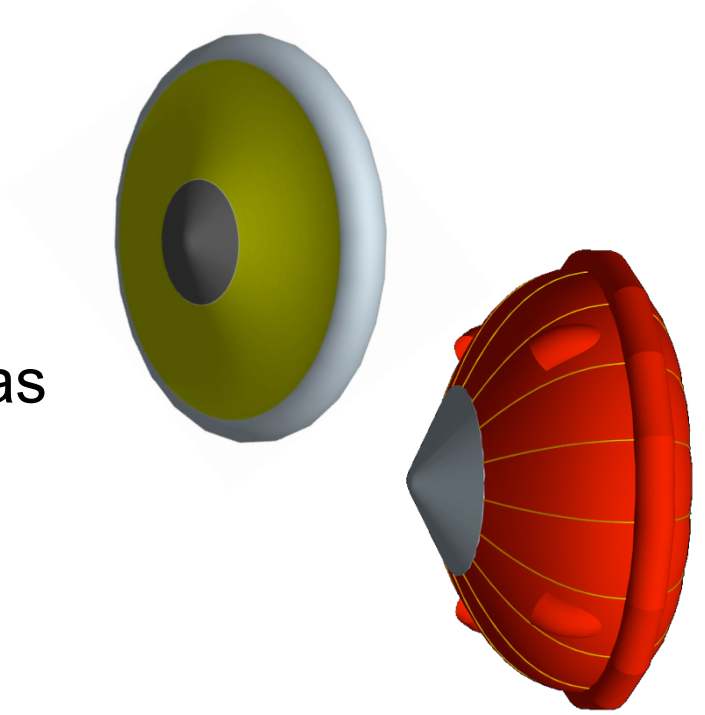
- Supersonic IADs are alternate technology to supersonic parachutes
  - Attached to the entry vehicle around its maximum perimeter
  - Deployed after peak entry heating
  - Mach ≤ 5

- Decrease entry vehicle ballistic coefficient $\beta = \frac{m}{C_D A}$
  - Textile construction
  - Diameters ranging from 5 to 15 m

- Enable future robotic missions to Mars
  - Greater landed mass
  - Higher landing altitude

Inflatable Aerodynamic Decelerators (IADs)

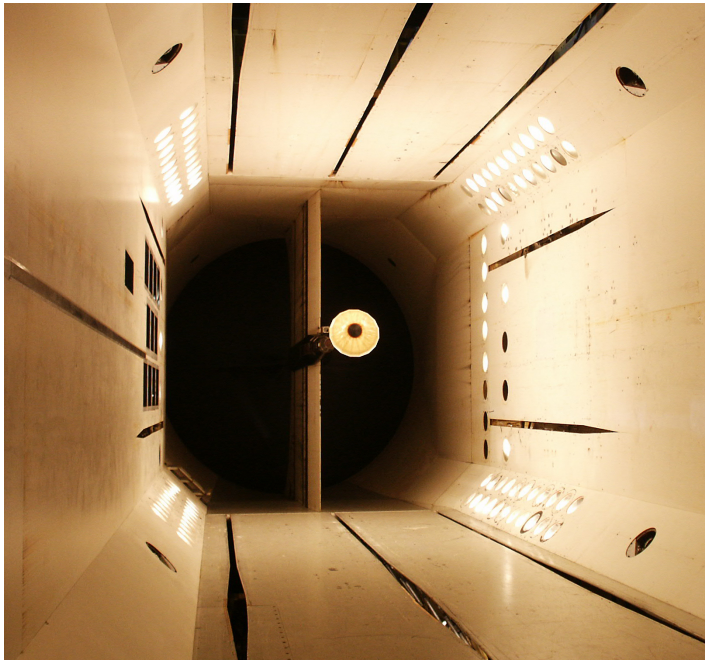
- Candidate designs:
  - Tension cone
  - Attached isotensoid



- Supersonic wind tunnel testing has been performed on both designs
  - Good drag performance
  - Rapid, stable inflation
- Transonic and subsonic testing had not been performed
  - Aerodynamic performance and stability are not quantified in these regimes
  - Data needed for ground acquisition and lander separation analyses

Transonic Testing

- Testing was performed in the Transonic Dynamics Tunnel (TDT) at the NASA Langley Research Center



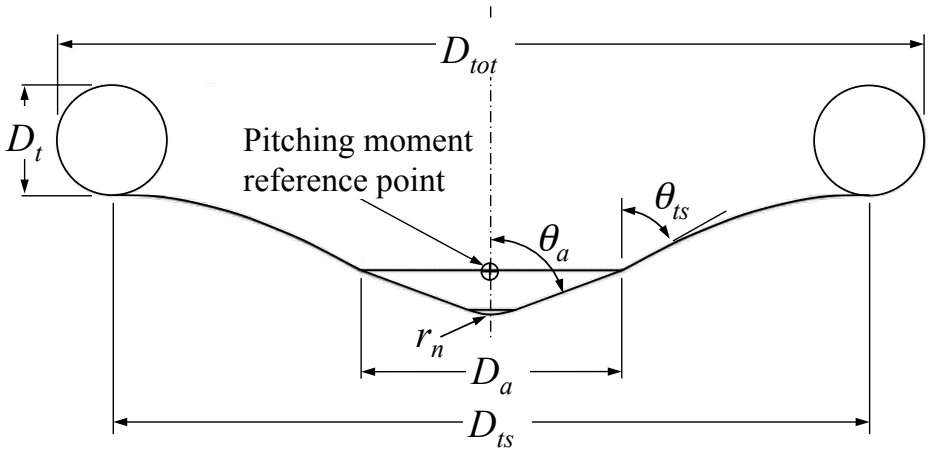
- Test Objectives:
  - Quantify static aerodynamic performance
  - Quantify static aeroelastic behavior
  - Investigate dynamic behavior

- Test Conditions
  - Mach range: 0.30 to 1.08
  - Reynolds number range: 250K to 2.5M
  - Angle of attack range: -5° to 15°

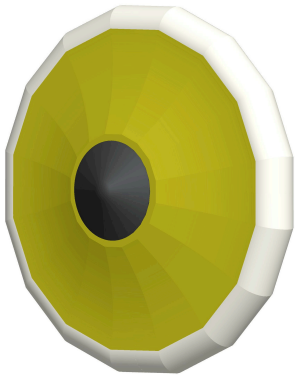
Tension Cone IAD

- Tension shell shape designed to carry only tensile stress when loaded

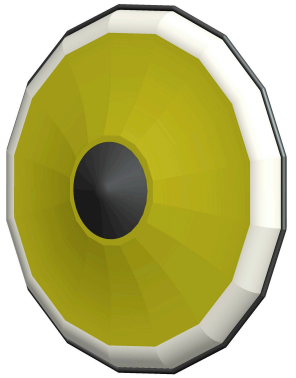
- Wind tunnel model:
  - 0.6 m total IAD diameter
  - 70° aeroshell
  - Flexible tension shell
  - Rigid torus
  - 16-sided polygon



- Two models: without and with burble fence
  - Burble fence is meant to enhance transonic and subsonic stability

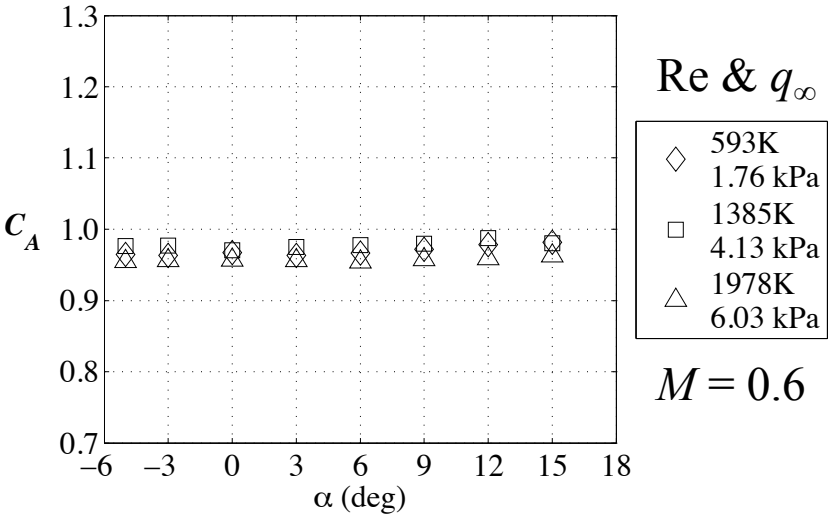


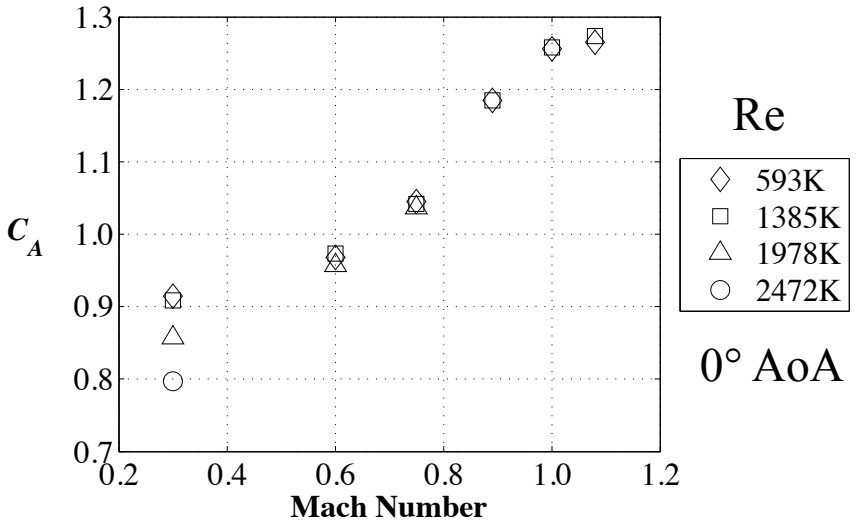
Model 1

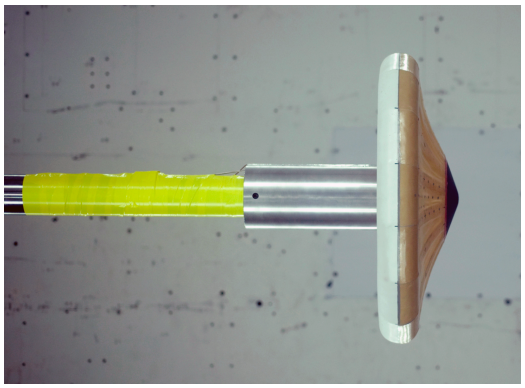


Model 2

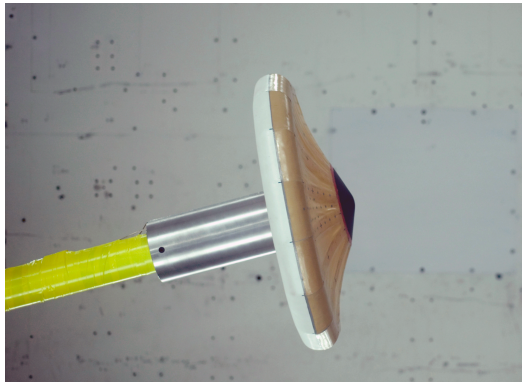
Static Aerodynamics





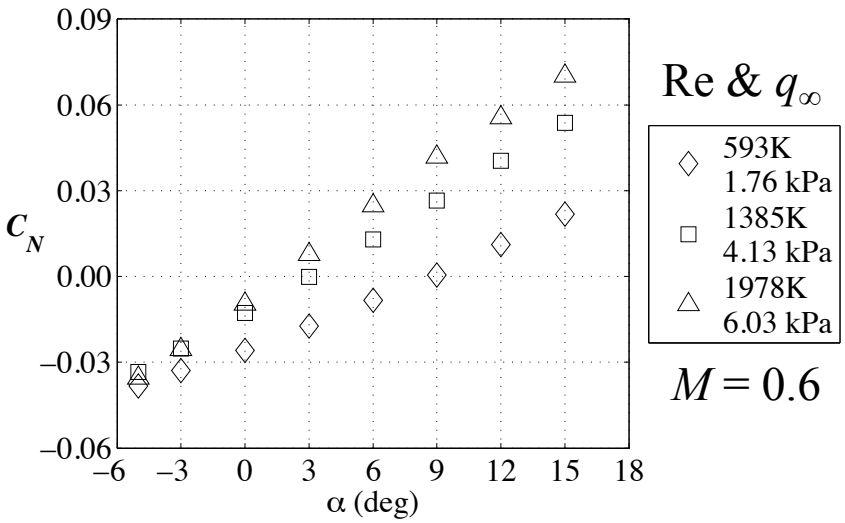


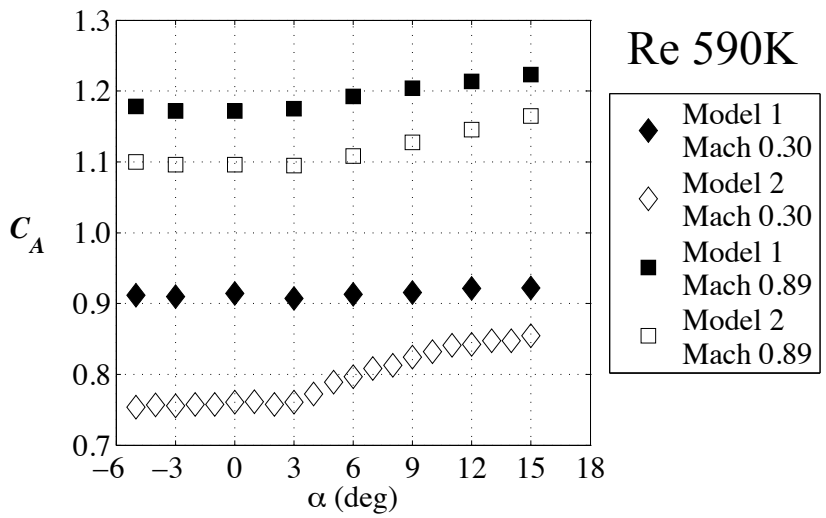
0° AoA

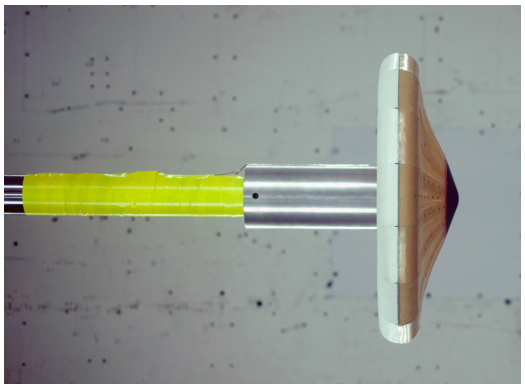


9° AoA

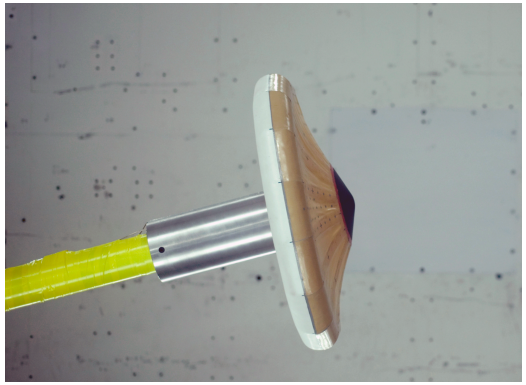
Static Aerodynamics







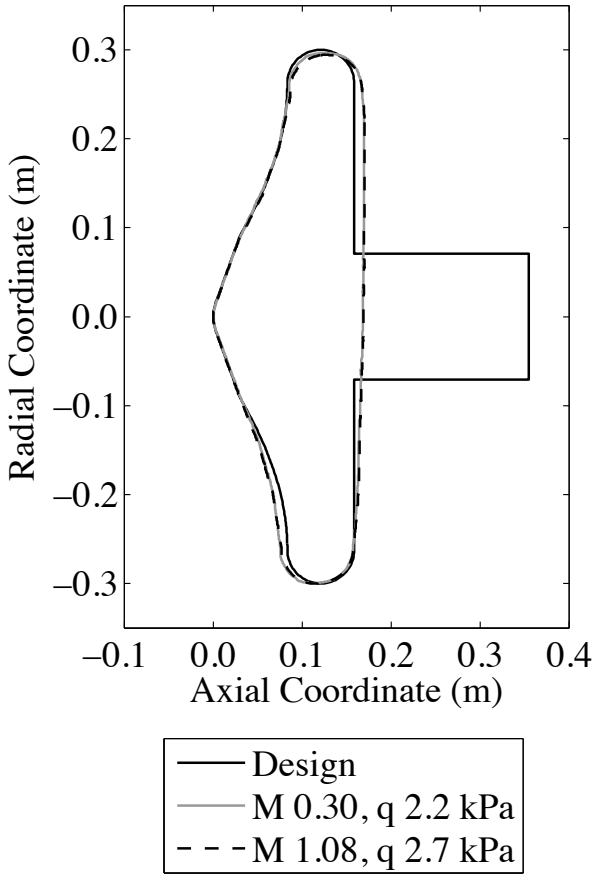
0° AoA



9° AoA

Aeroelastic Behavior

- Profiles extracted from high resolution images
- Essentially same profile at M = 0.3 and 1.08, similar to design shape
- Models exhibit slight nose-up pitch (approx. 0.7°) at 0° AoA due to weight of torus



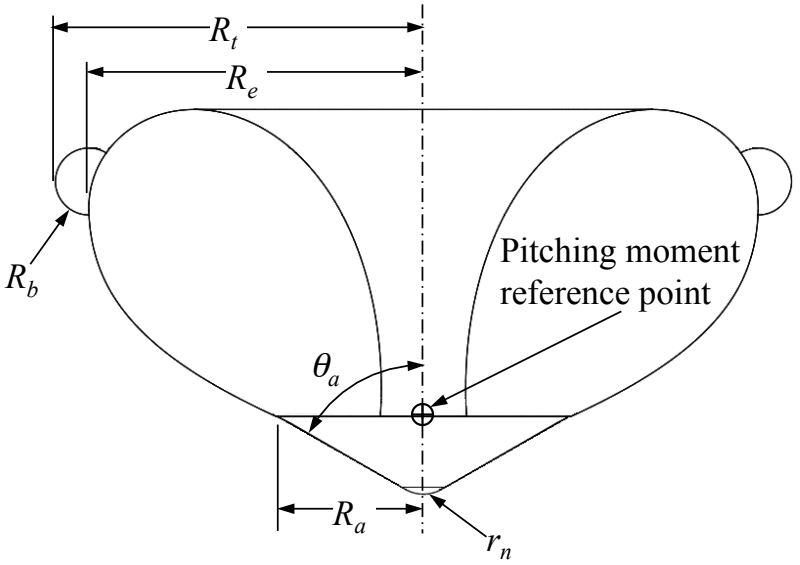
Aeroelastic Behavior

- Tension cone oscillates at subsonic speeds [video]
  - 0° AoA [DVR3 501]
  - 9° AoA [DVR3 502]
- Burble fence relatively ineffective in controlling oscillations [DVR3 933]
- Very stable at supersonic speeds

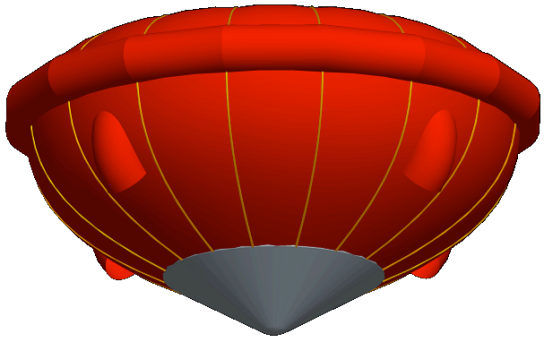
Isotensoid IAD

- Isotensoid shape designed to carry uniform fabric stress and constant meridional cord tension

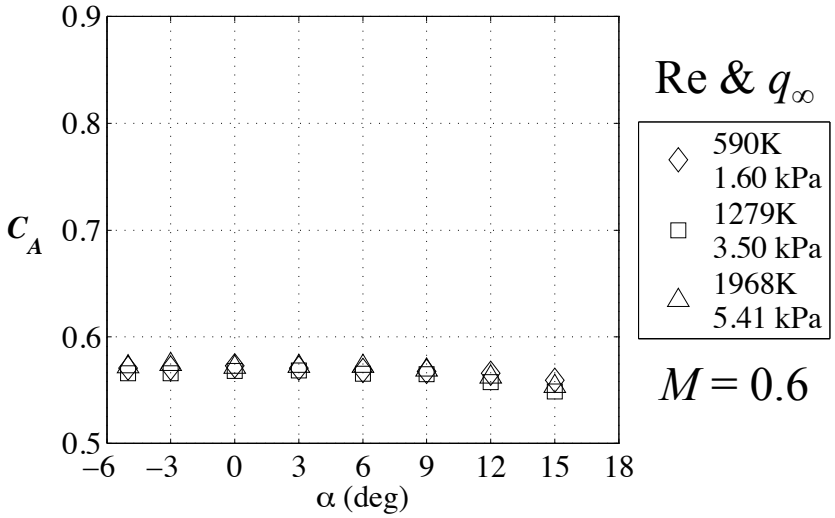
- Wind tunnel model:
  - 0.66 m design diameter
  - 60° aeroshell
  - Ram-air inflated
  - Burble fence
  - 16-sided polygon

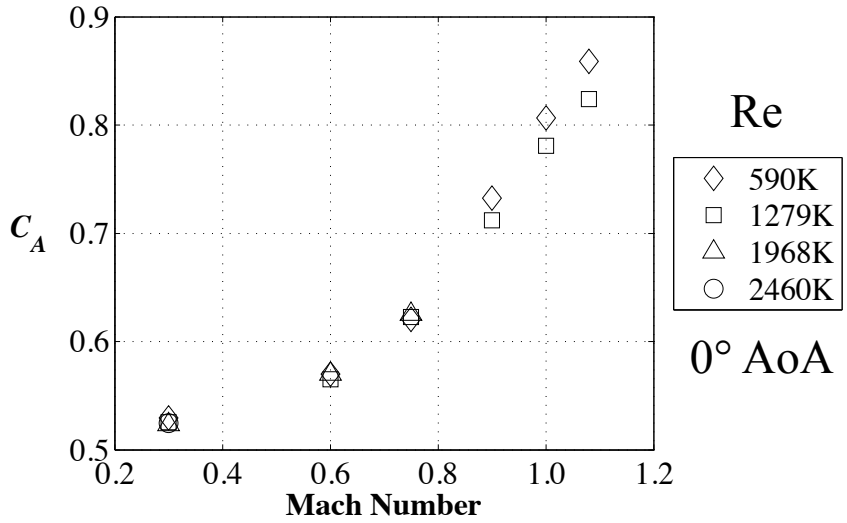


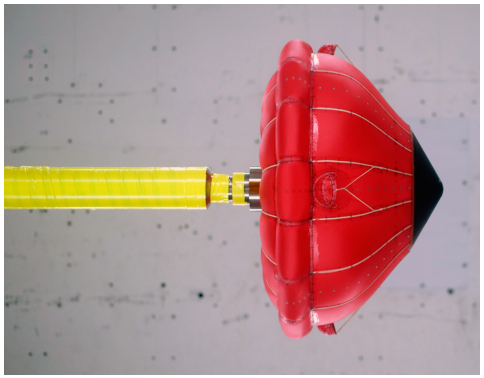
- Two identical models



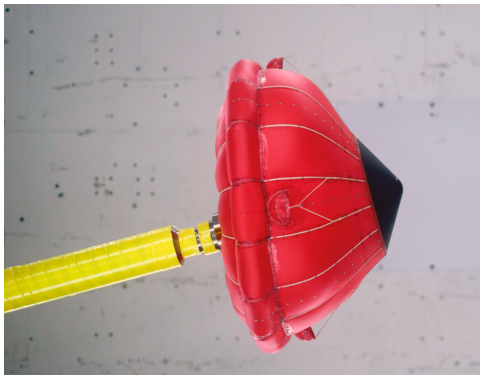
Static Aerodynamics





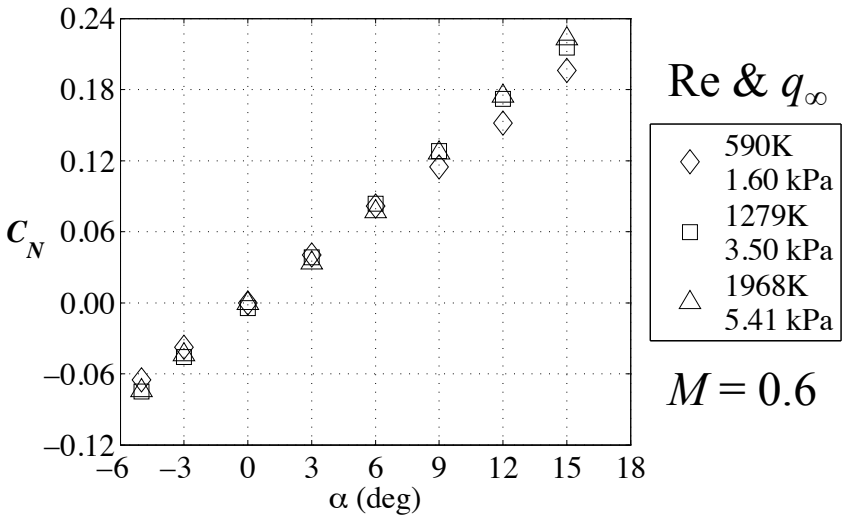


0° AoA



9° AoA

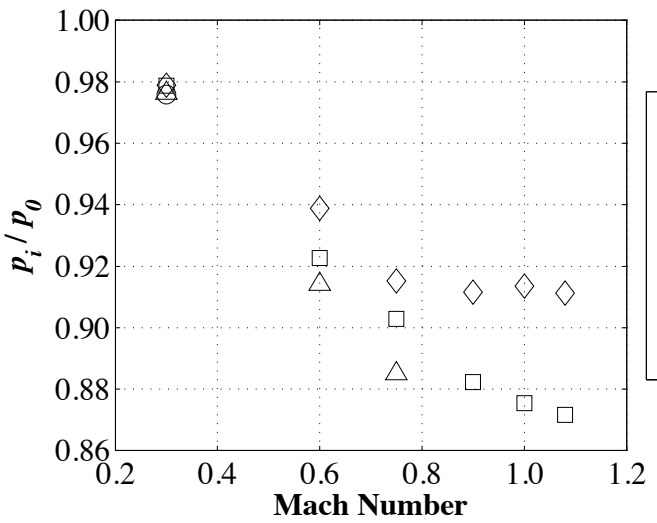
Static Aerodynamics



Re & q_∞

590K 1.60 kPa
1279K 3.50 kPa
1968K 5.41 kPa

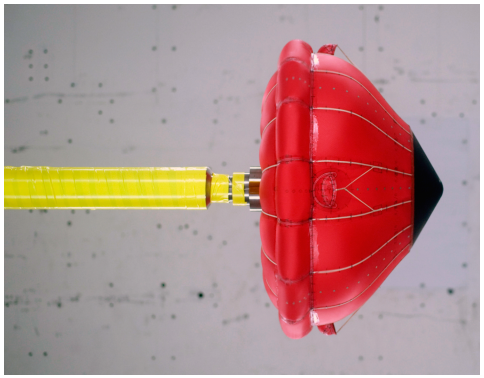
$M = 0.6$



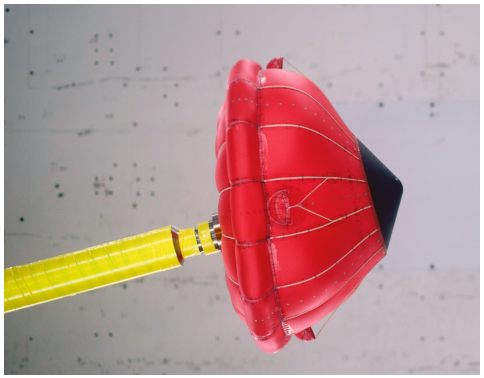
Re & q_∞

590K 1.86 kPa
1279K 3.77 kPa
1968K 4.24 kPa
2460K 3.53 kPa

0° AoA



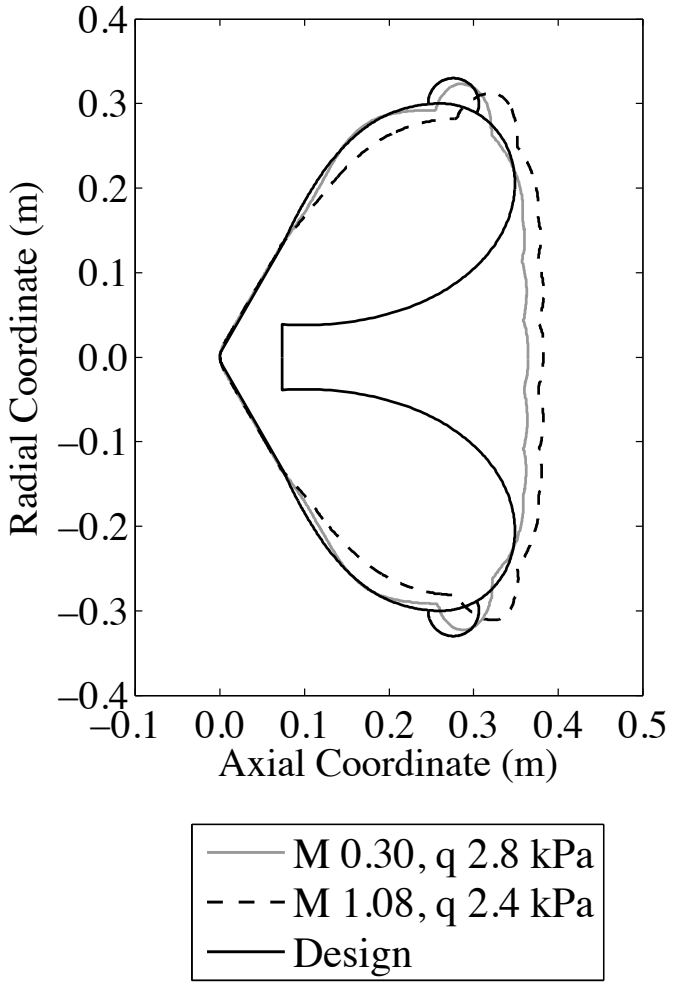
0° AoA



9° AoA

Aeroelastic Behavior

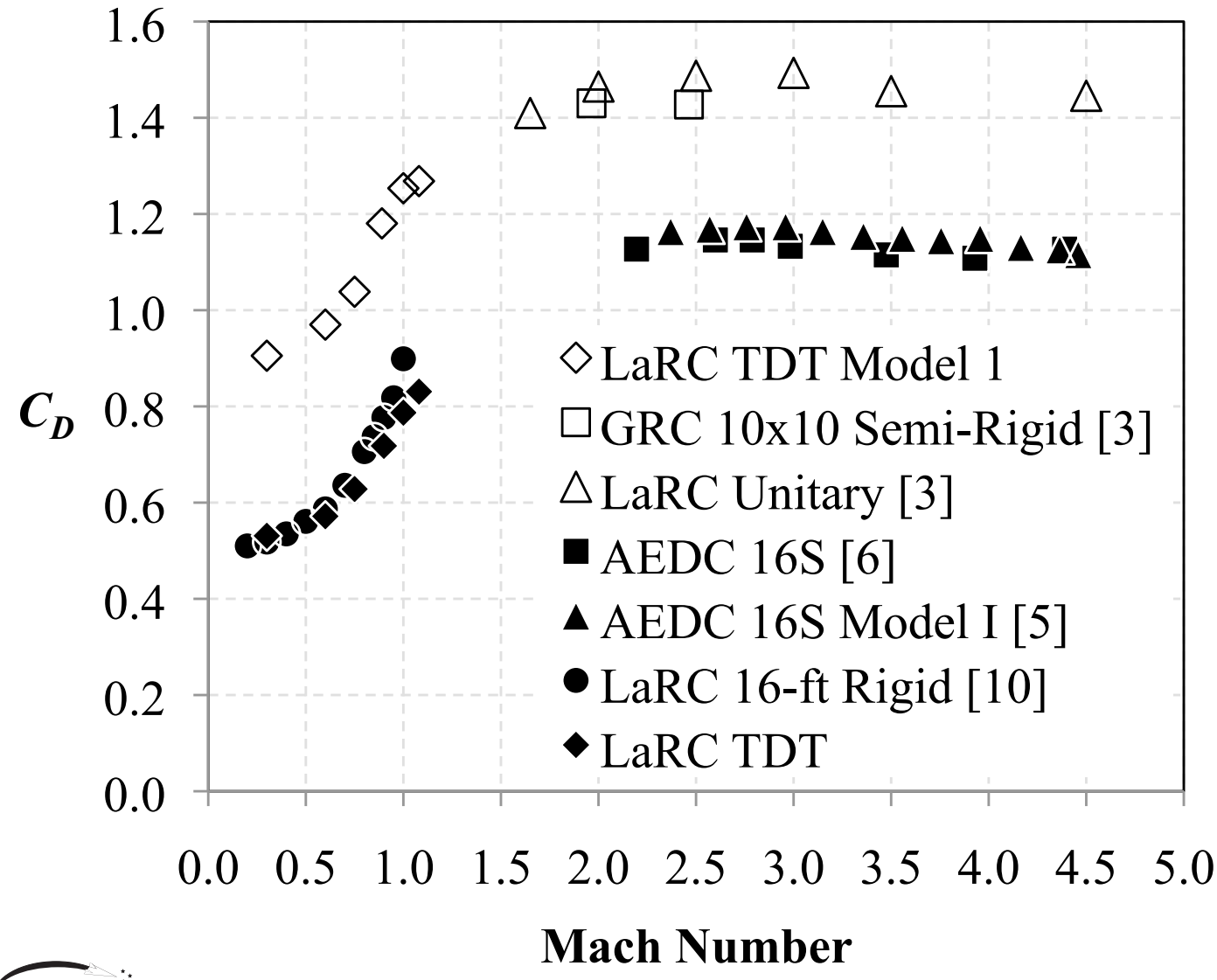
- Profiles extracted from high resolution images
- Isotensoid shape design at supersonic conditions
  - Subsonic shape very close to design shape
  - Transonic shape considerably different than design shape
- Shape is a function of internal pressure, windward pressure distribution, and back pressure

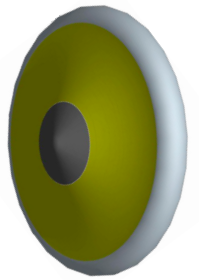


Aeroelastic Behavior

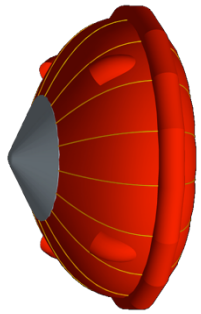
- Dynamic motion at subsonic speeds
  - 0° AoA [DVR4 492]
  - 9° AoA [DVR4 495]
- Stable at supersonic speeds

Supersonic IAD Summary





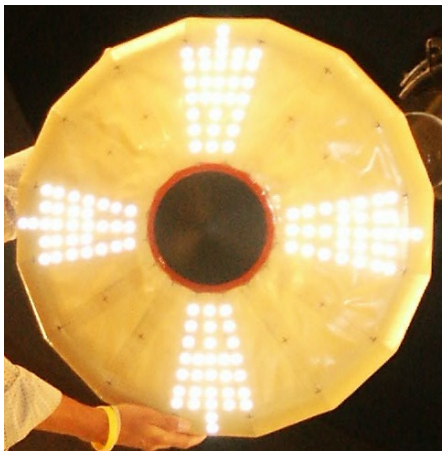
Tension Cone
Open Symbols



Isotensoid
Filled Symbols

Continuing Work

- Estimate uncertainties of aerodynamic coefficients



- Reduce photogrammetry data
  - In-situ measurement of decelerator shape
  - Torus offset angle
  - Tension cone oscillation frequency

- Publication of complete results in NASA technical report

Acknowledgements

- Personnel at NASA Langley Research Center
  - Atmospheric Flight and Entry Systems Branch
  - Advanced Sensing and Optical Measurement Branch
  - Transonic Dynamics Tunnel

- ILC Dover
  - Model design and fabrication